Model Course Mapping Resource
A Resource Developed by the Michigan Science Standards Review Team
To Support Options for Meeting Michigan Merit Curriculum Requirements
and Scientific Literacy

Rev. 10-16-14

Considerations for Developing Science Courses to Meet Michigan Merit Curriculum Requirements

Since the Michigan Merit Curriculum (MMC) was established, a growing body of research has provided significant insights on how science standards should be implemented and what instructional aims should be prioritized. Program design and curriculum implementation should be shaped by these insights so that science education in Michigan reflects the most current, state-of-the-art principles and practices. The National Research Council (NRC) has published "A Framework for K-12 Science Education" (NRC Framework) which presents the culmination of these findings and proposes what is no less than a *new vision* for science education. Educational leaders and science educators need to attend to the following tasks in order to maximize the impact of this important resource:

- Study the vision for science education proposed by the NRC Framework (free download: http://www.nap.edu/catalog.php?record_id=13165) which emphasizes the development of student proficiency in *doing* science.
- Carefully study the three dimensions of science proficiency: science and engineering practices, crosscutting concepts, and disciplinary core ideas.
- Consider the implications of the assertion that the three dimensions of science proficiency must be integrated so that science content is understood and applied through connections to the science and engineering practices and crosscutting concepts (3-dimensional learning).
- Study the principles around and recognize the importance of building learning progressions into science courses and programs.

Implementing Insights from "A Framework for K-12 Science Education"

While this document presents a set of tools to support secondary course sequencing, the central activity that brings the NRC Framework vision to life is classroom instruction and assessment. To that arena and to those related to program restructuring, the following projects should be implemented:

- Teachers should spend significant effort working on their comprehension of the NRC Framework vision. They should collaboratively study the NRC Framework document, supporting resources from groups like the National Science Teachers Association (NSTA), and new model units and lessons.
- Teachers should develop significant expertise in the practices and crosscutting concepts through study of the NRC Framework and by engaging in professional development. A very compelling review of the three dimensions is provided by a set of videos at http://www.bozemanscience.com.
- Teachers should analyze their current instructional practice in light of the NRC Framework. Manageable shifts in instructional design should be implemented by integrating the science and engineering practices and crosscutting concepts, which represent a refinement of the goals of the MMC Science Course/Credit Requirements.
- Review the K-12 topic progressions and consider the implications for course sequencing in secondary schools.
- Consider topics and practices already being addressed in current courses and how they support one another grade to grade, or course to course.
- Begin to plan for a workable transition, including plans for rearranging course offerings, and building a coherent K-12 plan for meeting the MMC.

Middle School (MS) and High School (HS) Course Models

Numerous 6-12 course models are described below as a resource for transition planning for future course offerings and hiring decisions. The model courses are listed in three groups: Adapted Models, Innovative Ideas for Consideration, and Models that Reflect Current Practice in Michigan.

- While both the MMC requirements and the NRC Framework include expectations for Physics, Chemistry, Biology, and Earth and Space Science, districts are not constrained by a requirement to organize them in courses with those names. In regard to high school, the "credit, not course" principle that accompanies the MMC accommodates creative and inspired innovations in course sequence as long as required graduation credits can be granted based on thoughtful placement of HSCE within the sequence.
- Courses centered on areas of application (such as agricultural science, or engineering) are proposed with the recognition that expectations can be treated with different degrees of emphasis, and that some can be treated as a bundle in service of a larger concept. This perspective should alleviate concern that all content expectations are of equal standing and that each must be addressed with specific lessons. That approach would in fact undermine the intent of the NRC Framework vision and the MMC.
- The three dimensions of the NRC Framework clearly define career and college readiness in science and should be considered a more than adequate treatment of the MMC.
- All recommended models should allow for meeting ALL HS expectations in three years of HS coursework (9-11 to be nearly completed by the Spring Grade 11 State Assessment). Any models that indicate a four-year plan should also indicate options of integrating necessary topics before state assessment in Grade 11.

Tools for Planning

- Course Models
- Strengths and Challenges for each model
- Tool for mapping Framework topics to current practices (course offerings, units of instruction), identifying gaps, planning for filling gaps, planning for the future

Sample Science Model Course Pathway Options (developed by Michigan Science Standards Review Committee)

6th Grade	7th Grade	8th Grade	Model	9th Grade	10th Grade	11th Grade	12th Grade	Comments*
Adapted Models – Adaptations of Models Recommended for Meeting the NRC Framework								* See more thorough discussion of strengths and challenges of these models in subsequent pages.
Physical Science (+)	Life Science (+)	Earth Systems Science (+)	Conceptual Progression (Appendix K)	Physical Science (+)	Biology (+)	Earth Systems Science (+)	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	By title the high school courses appear to be a standard science domain model, but careful mapping of learning progression has topics placed in each course as they support learning in the subsequent courses.
Physical Science	Life Science	Earth Systems Science - Since HS ESS after MME, add some HS ESS to 8th	Physics First Conceptual Model Expanded to 4 Years HS Science	Physics	Chemistry	Biology	Earth and Space Science	As a capstone course Earth and Space Science will review and apply P, C, and B, and address many highly relevant issues students will confront as adults. To prepare for an eleventh grade assessment Earth and Space Science topics should be included in P, C, and B as application projects.
Physical Science OR Integrated Science	Life Science OR Integrated Science	Earth Systems Science OR Integrated Science	Integrated ESS	Physics (Astronomy)	Chemistry Earth Systems (Geology, Weather and Climate)	Biology Earth Systems (Environmental, History of Earth)	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	Programs that bring teacher expertise in Earth and Space Science into the Chemistry and Biology courses will be needed or the treatment of those topics will not provide the depth necessary for meeting the high school expectations.
Physical Science Life Science Earth/Space	Physical Science Life Science Earth/Space	Physical Science Life Science Earth/Space	Multi-Topic Science Similar to MS GLCE and as in other countries	Physics (Astronomy) Geology (Macro, including plate tectonics)	Chemistry and Biology (Biochemistry)	Environmental Biology Earth Systems Science (Evolution, climate change, human impact)	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	The clusters presented here are mere examples of the concepts. Many reasonable groupings could be construed.
Innovative Ideas for Consideration – (with 6-8 following either organization above)								* See more thorough discussion of strengths and challenges of these models in subsequent pages.
			STEM Centric Application drives science; real-world issues	Material Science	Bioengineering	Natural Resources and Energy Use	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	The STEM areas presented here are merely examples of the concept. Many reasonable groupings could be construed.
			Career Clusters Agro-science Biosciences Seq. Energy Sequence Engineering Cluster Geosciece Seq. Medical Sequence	Physical Science	Earth Systems BioGeoScience	- Medical Program - Energy and Innovations Program - Engineering and Technical Program	- Medical Program - Energy and Innovations Program - Engineering and Technical Program	The programs presented here are merely examples of the concept. Many reasonable groupings could be construed.
			Societally Relevant Science (Ontario Emphasis Model)	Nanotechnology Energy and Resource Needs	Global Climate Water Crisis Bioethics	Environmental Chemistry Food Chemistry	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	The topics presented here are mere examples of the concepts. Many reasonable groupings could be construed.

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Models That Reflect Current Practice in Michigan								* See more thorough discussion of strengths and challenges of these models in subsequent pages.
Multi-topic (a.k.a., Integrated) Science P, L, ESS (MS)	Multi-topic (a.k.a., Integrated) Science P, L, ESS (MS)	Physical Science (HS)	**B, C, ESS**	Biology	Chemistry	Earth Science / Environmental Science	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	This model condenses most middle school expectations into Grades 6 and 7 and addresses most high school Physical Science expectations in Grade 8. Meeting only middle school Physics expectations would not suffice as students will not have the foundation necessary for meeting high school Biology, Chemistry, and Earth and Space Science expectations.
Multi-topic (a.k.a., Integrated) Science P, L, ESS (MS)	Multi-topic (a.k.a., Integrated) Science P, L, ESS (MS)	Earth and Space Science (HS)	**B, C, P**	Biology	Chemistry	Physics	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	This model condenses most middle school expectations into Grades 6 and 7 and addresses most high school Earth and Space (ESS) expectations in Grade 8. Many HS ESS expectations are too sophisticated to be addressed without foundations from high school Physical Science and Biology.
Life and Physical	Life and Physical	Earth Space Science (MS, HS)	**B, C, P,**	Biology	Chemistry	Physics	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	This model has the same issues as the one above but suggests that there is time in middle school for high school Earth Space and Science content in Grade 8. That would be difficult to accomplish.
Multi-topics (a.k.a., Integrated) Science	Multi-topics (a.k.a., Integrated) Science	Physical Science Emphasis (HS)	**ESS, B, C**	Earth and Space Science	Biology	Chemistry	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	Like the top model, this one lacks the high school Physics that undergirds the other three disciplines. With Earth and Space Science and Biology preceding the Chemistry course, the opportunity to provide a deeper treatment of these disciplines and review Chemistry in context is lost. Middle school Physics will not suffice for high school because it is less sophisticated.
Multi-topic (a.k.a., Integrated) Science	Multi-topic (a.k.a., Integrated) Science	Earth and Space Science (MS, HS)	**PS, B, C**	Physical Science	Biology	Chemistry	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	This model suggests that MS and HS ESS expectations could be met in Grade 8. Many HS ESS expectations are too sophisticated to be addressed without foundations from HS Physical Science and Biology.
Physical Science	Life Science	Earth and Space Science (MS, some HS)	**PS, ESS, B**	Physical Science	Earth Science	Biology	Optional Advanced Science Courses (AP, IB, H, Dual Enrollment)	While not common, subject specific middle school courses are being enacted in Michigan. With some tweaking, these courses may be adapted to reflect the conceptual progressions model above.

Proposed Trimester HS Model

		8th Grade	ERPS Proposed	Over 6+ trimesters in 9th, 10th (and part of 11th) Grades (Some students will complete by end of 10th)				
		Basics for HS PEs ESS, B, PS	Two trimesters each of B, C, P and one trimester ESS Offer Regular and Advanced B, C, P	Biology - 1 Ecosystems and Cells Chemistry -1 Properties and Bonding	Physics - 1 Waves Biology -2 Biochemistry ESS	Physics – 2 Forces Chemistry – 2 Equilibrium and Heat		
								Additional trimester models in use in Michigan will be added.

Transitioning to the NRC Framework

A school may feel compelled to transition to one of the Adapted or Application Centric Models from one that is more commonly enacted. Depending on local factors (teacher endorsements, special interests, or local assets) this change effort may be more or less difficult. Transitioning to an intermediate sequence may be necessary to give time for new courses to be designed or resourced.

Descriptions of Each Model Course Pathway (listed above)

Key: P – Physics, C – Chemistry, B – Biology, ESS – Earth Systems Science, PS – Physical Science
ENV – Environmental Science, G – Geology, CCC -- Crosscutting Concepts, PD – Professional Development

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Conceptual Progressions Model		
This model spirals through science topics from sixth to eighth and again from ninth through eleventh grades. Both sixth and ninth are organized around topics in Physical Science, including Astronomy. Seventh and tenth grades are centered on Life Science topics. Eighth and eleventh grades address Earth and Space Science while reinforcing biological evolution, since coevolution in the biosphere and other Earth systems is an important big idea. The sequence is designed to build conceptual understanding over time using well-mapped learning progressions. Deep treatment of the Life and Earth Sciences depends on a foundation in Physics, Chemistry and Mathematics. The foundational concepts around energy and matter are reinforced in the Life and Earth Sciences.		
	Strengths	**Challenges**
Overall	The progression is a strength; it provides opportunities for applying P and C in B and ESS. This model is a strong example of how the NRC Framework's learning progressions concept can be applied.	Staffing this sequence may present a challenge for some high schools. Endorsement policy and HQ rules have constrained PS. Many schools are in need of qualified ESS teachers.
Progressions	• P and C concepts are reinforced in Life and ESS. • Life and Earth are richer/deeper because of PS base.	• It may be difficult to thoroughly address all P and C expectations in one year unless they are organized around high priority concepts. (Physics First Model (below) extends this model to 4 years of HS science.)
HQ	• Biology teachers are in place.	• Those with P or C endorsements only cannot teach this as described. • Lack of HQ ESS teachers. • The temptation to split PS into a semester of P and C would undermine the progression when some teachers offered C before P. • Depth of content knowledge in both P and C necessary for PS.
Transitions	• Physical Science is not an uncommon HS course; schools that currently have PS in place will have fewer adjustments to move to this model.	• For schools w/o current PS, this could be problematic because of HQ law. • Would require more equipment for use by all 9th graders. • Will need intensive PD for teachers in Earth Systems Science, as well as recruitment.

Physics First Model (Conceptual Progressions Expanded to 4 Years of HS Science)		
This high school model is a typical Physics First design, which views Physics as the foundation of all other disciplines of science, therefore it is placed in the 9th grade. Because Chemistry is the foundation of modern Biology and critical to deeply understanding Earth and Space Science, it is placed next in the sequence. Also, modern Biology is currently one of the most dynamic areas of science, with extensive career opportunities and relevance to societal concerns. Placing it in 11th grade allows for a treatment that does justice to its importance. Earth Science, a set of disciplines of especially high societal relevance, applies Physics, Chemistry and Biology to questions related to our critical challenges regarding food, water, energy, risks to natural disasters and sustainability of ecosystems. This model allows for a strong, high level Earth Science capstone course in 12th grade. To the degree that the high school targets specific Earth Science content, there will need to be the means to expose students to the core concepts. This could include adding some high school topic placement in eighth grade, or use of online or application oriented projects in the other courses.		
	Strengths	**Challenges**
Overall	The progression is a strength; it provides opportunities for applying P and C in B and ESS. Ninth grade Physics complements student learning of Algebra by providing timely opportunities applications.	Staffing this sequence may present a challenge for some high schools. Many schools are in need of more Physics teachers and qualified ESS teachers.
Progressions	• P and C will be thoroughly addressed (full year of each). • P and C concepts are reinforced in Life and ESS. • Life and ESS are richer/deeper because of PS base.	• While the 8-12 HS grade band is in place districts will want to address some HS ESS HSCE in 8th Grade, since HS ESS is taught after the 11th Grade assessment.
HQ	Physics, Chemistry, and Biology teachers in place. (PS not a problem)	• Lack of HQ ESS teachers; may need additional teachers for C and P. • Even though taught in courses focusing on P, then C, still need to build integration and application across Physical Science concepts.
Transitions	• Schools that have PS in place will not have difficulty with transition to this model, but the expansion to two courses needs to be carefully planned.	• Would require more P and C equipment for use by all 9th and 10th graders. • Will need intensive PD for ESS teachers to be well-versed in Earth Systems Science.

		• Will need careful planning for ESS preparation in 8th Grade.

Integrated (Parsed) Earth Systems Science Model		
This model assigns Earth and Space topics to Physics, Chemistry, and Biology as they connect to those subjects. It assumes planned integration of ESS.		
	Strengths	**Challenges**
Overall	The progression is a strength; it provides opportunities for applying P and C in B. Earth and Space Science provides ample, relevant topics that can serve as applications of P, C, and B.	Staffing – expertise in Earth and Space Science will need to be available to teachers of P, C and B courses. Physics, Chemistry and Biology courses too easily fill an academic year; finding time to adequately treat Earth Science will be a challenge.
Progressions	• Great progression and conceptual flow (P, C, B). • Still address highest level of Environmental Biology in 3rd year.	• Need careful planning; will require a conscious effort to do justice to Earth Systems Science. • Biology is already crowded; difficult to find time for ESS/ENV.
HQ	• Physics, Chemistry, Biology teachers could teach the three courses in this model. • An Earth and Space teacher could rotate through courses across the grade band.	• Need strong ESS background so can teach P in the context of ESS, and can teach Biology in the context of ENV. • Need best practices workshop to do justice to ESS integration.
Transitions	• This model allows teachers who currently teach P, C, and B to continue to teach these courses, but with adaptations to address progression (P, C, B) and to integrate ESS. • Allows for rearrangement of topics within courses (and for some will not require moving content to new grade levels).	• Need careful planning for transitions, since all of ESS is taught within the context of P, C, and B. • Need strong ESS background so can teach P in the context of ESS, and can teach Biology in the context of ENV.

Multi-Topic Model (a.k.a. Integrated)		
This model distributes topics from Physical Science, Life Science, Earth Science and Engineering in each middle school and high school grade. Because there are four science disciplines, each would be placed in 3 of 12 quarterly slots. Topics can be strategically grouped to leverage logical progressions at each grade level. In Michigan this is typical in K-7, but not in high school. In Ontario, which has been very successful on international tests, this design is extended into grades 9 - 11.		
	Strengths	**Challenges**
Overall	This model is employed in some other very successful countries and regions. This model allows for logical progressions within a grade.	Staffing – expertise, necessary PD, possible certification issues. Other countries that use this model incorporate system features that connect to and support this design (teacher preparation, resource use, etc.).
Progressions	• Biology is taught more in context than in other models. • Sets conceptual foundation; good conceptual flow.	• Shallow in P and C.
HQ	• Biology and Chemistry teachers can teach Biochemistry (may need additional PD). • Teachers HQ in Environmental Science can teach Biochemistry (may need additional PD).	• Need careful planning for concept building (practices and CCC). • Need to design to cover HQ issues w/o splitting content into two discipline-specific semesters; need strength of integration.
Transitions	• This model is an extension of the current plan many schools use for MS (5-7 or 6-8).	• Limited support materials for this option; practices are at the heart of this change. • Other countries who use this educate pre-service teachers to teach such courses explicitly using the very resources available to the classroom. This is not our current system.

Sample Science Model Course Pathway Options (developed by Michigan Science Standards Review Committee)

STEM – Centric Model		
This sequence provides examples for emphasizing the application of Framework topics in currently exciting and highly relevant fields. By engaging science students through application, the practices are especially well treated and the content (DCI and Crosscutting Concepts) is strongly connected to the real world scientific fields as well as personal learning experiences. Students gain experience in conducting investigations and solving problems in these fields. These courses can develop a robust conceptual understanding of science content while making prominent its relevance to society and career opportunities. Material science could be an excellent avenue to apply Physical Science, bioengineering or genetics could provide the same for the Life Sciences, and natural resources and energy use could focus investigations and problem solving in the Earth Sciences.		
	Strengths	**Challenges**
Overall	The STEM model promotes application of science knowledge and practice.	Care must be taken to assign topics to courses in a way that aligns with the intended STEM focus, while allowing for all expectations to be addressed.
Progressions	The progression can be carefully planned to reflect application of the topics included in the conceptual progression model.	Will want to plan for more integration since some of the topics will not relate directly to planned STEM units.
HQ	Similar courses may already be taught in CTE programs.	HQ issues – may require team teaching of science HQ teachers with CTE teachers.
Transitions	Schools with special staff or community expertise/experience could leverage such resources in course design and student learning opportunities.	Teachers will need to develop deeper understanding of the applications and field of whatever STEM emphasis is determined.

Career Clusters Model		
This high school sequence organizes important selected topics of Physical Science, Biology and Earth Science into ninth and tenth grade in order to allow students to pursue career focused education. Programs in eleventh and twelfth grade include content and practices connected to the STEM fields of the programs. Conventional high schools could develop career academies in STEM fields such as agro-sciences, geosciences, engineering, medical, information technology or innovations related to energy. Career technical centers could accommodate students in a similar manner.		
	Strengths	**Challenges**
Overall	Many students would be better served if our educational system more explicitly provided promising career education programs, rather than the current over emphasis on academic goals. High quality models and resources exist.	While high quality resources and models exist in high schools and career-technical centers, they are currently under-utilized. Schools might place more students in these courses if they had evidence that the courses address all mathematics and science standards as assessed.
Progressions	A Physics First sequence can be applied across two years, and career clusters continue to apply science practices and conceptual understanding.	• 9-10 progression will need to be carefully planned to address any expectations that are not addressed in specific Career Program. • Health program may be able to address some Chemistry and Biology expectations in 11 and 12, so will need to address all other expectations in 9 and 10.
HQ	Similar courses may already be taught in CTE program.	• HQ issues – may require team teaching of science HQ teachers with CTE teachers.
Transitions	Schools that have access to existing career and technical programs and facilities can leverage these resources.	• Would require coordination with local resources such as work place settings for internships and career-technical centers for special expertise.

Societally-Relevant Science Model		
This sequence is organized around societally or economically relevant topics. It puts what's interesting and important in the forefront of curriculum. By engaging the science learners through important questions, issues and cutting edge science, the practices and crosscutting concepts would be especially well treated and the content would be strongly connected to real world issues and opportunities. These types of courses can develop more a robust conceptual understanding of science content while making prominent its relevance to society. Courses built around topics such as nanotechnology, energy and resources needs, global climate change, the global water crisis, environmental or food chemistry are examples of compelling and critical issues.		
	Strengths	**Challenges**
Overall	No student could be confused by the notion that science does not connect with their life and society as a whole. Having the relevance prominent in an engaging curriculum will inspire more students to pursue scientific fields. Citizens will hold science in the regard it deserves when faced with the challenges of our time.	Curriculum will require prompts, routines and support for issue-based curriculum. Teachers will need to guard against drifting to a state of low-science rigor, as analysis of social systems takes up a larger portion of the science course.
Progressions	• Issues can be selected and organized in a way consistent with the conceptual understanding/progression model.	• A sequence built around issues could present concepts in orders not as optimal as other more ideal learning progressions.
HQ	• Issue-based course titles alleviate the hurdles presented by highly qualified law. The central discipline of an issue could guide teacher assignment. For example nanotechnology would be best taught by a physical science teacher	• Many issues are multidisciplinary at least in part, putting some teacher out of area.
Transitions	• More resources are now available from major publishers for issues based science courses.	• New equipment and resources would be needed in order to engage students in new issues based projects. • Will need intensive PD for teachers to be well-versed in content related to issues and skill in facilitating a problem based curriculum. • The most important issues tend to change over time requiring continuing monitoring and repurposing of courses.

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Describe your district's current focus for each grade/course.

Identify Framework topics currently addressed in each (content with or without practice).

List Framework topics to be assigned to courses.

See MS and HS Topics List (below).

See also Topic Alignment document (comparing Framework with MI GLCE/HSCE).

6th Grade	7th Grade	8th Grade	Model	9th Grade	10th Grade	11th Grade	12th Grade
			Focus				
			Topics				

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MS and HS Topics Aligned with Framework

Life Science / Biology	Earth Systems Science	Physics and Chemistry
HS.SF Structure and Function **HS.IVT** Inheritance and Variation of Traits **HS.MEOE** Matter and Energy in Organisms and Ecosystems **HS.IRE** Interdependent Relationships in Ecosystems **HS.NSE** Natural Selection and Evolution	**HS.SS** Space Systems **HS.HE** History of Earth **HS.ES** Earth's Systems **HS.WC** Weather and Climate **HS.HI** Human Sustainability	Chemistry **HS.SPM** Structure and Properties of Matter **HS.CR** Chemical Reactions Physics **HS.FI** Forces and Interactions **HS.E**N Energy **HS.WER** Waves and Electromagnetic
MS.SFIP Structure, Function, and Information Processing **MS.GDRO** Growth, Development, and Reproduction of Organisms **MS.MEOE** Matter and Energy in Organisms and Ecosystems **MS.IRE** Interdependent Relationships in Ecosystems **MS.NSA** Natural Selection and Adaptations	**MS.SS** Space Systems **MS.HE** The History of Earth **MS.ES** Earth's Systems **MS.WC** Weather and Climate **MS.HI** Human Impacts	**MS.SPM** Structure and Properties of Matter **MS.CR** Chemical Reactions **MS.FM** Forces and Interactions **MS.EN** Energy **MS.WER** Waves and Electromagnetic Radiation